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Authority in the Context of Distributed Knowledge

by

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Abstract
The notion of distributed knowledge is increasingly often invoked in discussions of economic organization. In particular, the claim that authority is inefficient as a means of coordination in the context of distributed knowledge has become widespread. However, very little analysis has been dedicated to the relation between economic organization and distributed knowledge. In this paper, we concentrate on the role of authority as a coordination mechanism under conditions of distributed knowledge, and also briefly discuss other issues of economic organization. We clarify the meanings of authority and distributed knowledge, and criticize the above claim by arguing that authority may be a superior mechanism of coordination under distributed knowledge. We also discuss how distributed knowledge influences the boundaries of firms. Our arguments rely on insights in problem-solving and on ideas from organizational economics.

Key words: Distributed knowledge, existence of authority, problem-solving, the boundaries of the firm
JEL Codes: L22, L23, M12

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Introduction

This paper addresses the impact of distributed knowledge on economic organization, particularly the use of the authority relation. The notion of distributed knowledge, coined in computer science about a decade ago (Halpern and Moses 1990), has fast become a household concept in various branches of management and organization studies (e.g., Marengo 1995; Cohen and Regan 1996; Tsoukas 1996; Lessard and Zaheer 1996; Gherardi 1999; Coombs and Metcalfe 2000; Larsen 2001; Potts 2001; Spangler and Peters 2001). Loosely, "distributed knowledge" is knowledge that is not possessed by any single mind, but "belongs to" a group of interacting agents, somehow emerges from the aggregation of the (possibly tacit) knowledge elements of the individual agents, and can be mobilized for productive purposes.

Many writers have argued that such distributed knowledge is becoming more and more important in an innovation-rich, knowledge-based economy. This is because firms increasingly need to rely on a growing number of knowledge specialists, be they employees or outside knowledge agents, such as supplier firms or universities (e.g., Granstrand, Patel and Pavitt 1997; Hodgson 1998; Coombs and Metcalfe 2000; Smith 2000; Wang and von Tunzelman 2000; Brusoni, Prencipe and Pavitt 2001). This tendency is seen as having strong transformative implications for the boundaries of the firm (Coombs and Metcalfe 2000; Foss 2001) as well as for internal organization (Cowen and Parker 1997; Foss 1999), including the use of authority as a mechanism of coordination (Grandori 1997, 2002).[1] However, although the concept is often invoked, there is little systematic analysis of how distributed knowledge and economic organization relate.

In this paper, we undertake a more systematic analysis of the relation between distributed knowledge and an important aspect of economic organization, namely the use of authority as a mechanism of coordination. We also briefly discuss the boundaries of the firm in the context of distributed knowledge. Our arguments draw on organizational economics ideas (e.g., Milgrom and Roberts 1992; Cremer 1993; Williamson 1996; Foss 2002), as well as on insights in problem-solving, derived from the work of mainly Simon (1962, 1973).

The critical starting point for our discussion is the increasingly prevalent argument (see Minkler 1993; Hodgson 1998; Foss 1999; Radner 2000), most starkly formulated by Grandori (2002: 257): "Distributed knowledge causes authority (as a centralized decision-making system) to fail in all its forms." This statement rely on an argument that has two steps. First, it is argued that authority — that is, the right to make decisions which guide the decisions of another person (Coase 1937; Simon 1951, 1991) — presupposes considerable knowledge about the capabilities and action set that is available to those that are being directed. Second, the presence of distributed

[1] By "coordination," we mean consistency of plans. By "coordination mechanisms," we refer to those mechanisms that may assure such plan-consistency, such as prices, authority, norms/rules/routines/standards/focal points (i.e., mechanisms that are based on behavioral regularities), consultation and ratiocination (e.g., in games). For a fine discussion of coordination mechanisms and their implications for organizational theory, see Grandori (2001).

knowledge means that this condition cannot be fulfilled (Minkler 1993; Hodgson 1998; Foss 1999; Grandori 1997, 2002). A further argument then suggests that alternative coordination mechanisms (Grandori 2001) will substitute for authority to meet the need for coordination that still exists under distributed knowledge (Zucker 1991; Liebeskind et al. 1995; Cowen and Parker 1997; Grandori 1997, 2002).[2] We analyze this claim and its supporting arguments, and arrive at the conclusion that they do not stand up to scrutiny.

In the course of arguing these points we develop a broader notion of authority than the one associated with Coase (1937) and Simon (1951), define and discuss the notion of distributed knowledge, and take steps towards an efficient alignment framework that maps the efficient use of coordination mechanisms as depending on the nature of problem-solving and the characteristics of knowledge.

The design of the paper is as follows. We begin by taking a closer look at the meaning of the key notions, authority and distributed knowledge ("*The Notions of Authority and Distributed Knowledge*"). We then examine their interplay, which leads us to take issue with the argument that authority is an inefficient mechanism of coordination when knowledge is distributed. More positively, by relying on a problem-solving derived from Simon (1962, 1973) and on organizational economics we identify the conditions under which authority may be an efficient mechanism of coordination under distributed knowledge. We finally discuss the complicated link between distributed knowledge and the boundaries of the firm ("*Authority in the Context of Distributed Knowledge*"). Refutable propositions are derived.

The Notions of Authority and Distributed Knowledge

Authority

Organizational and behavioral theories, usually drawing on sociology and psychology, present a huge number of interpretations of authority (e.g., Weber 1947; Thompson 1956; Grandori 2001). This is not the place to present a full review and critical evaluation of the multitude of definitions and ideas regarding the notion of authority. Rather, for the purpose of this paper, the concepts of authority offered by Herbert Simon (1951, 1991) serve as useful starting points, because they are well known, relatively precise, and do not invite confusions with neighbouring concepts, in particular, leadership.

Simon (1951) defines authority as obtaining when a "boss" is permitted by a "worker" to select actions, $\mathbf{A}^0 \subset \mathbf{A}$, where $\mathbf{A}$ is the set of the worker's possible behaviors. More or less authority is then defined as making the set $\mathbf{A}^0$ larger or smaller. Simon develops a model (specifically, a multi-stages game in the context of an incomplete contract with *ex post* governance), where, in the first period, the prospective worker

[2] Note that these arguments implicitly are critiques of those theories of economic organization that place great emphasis on the authority relations as the mechanism of coordination that primary characterizes firms, notably transaction cost theories (Coase, 1937; Williamson, 1985) and property rights theory (Hart, 1995, 1996). Thus, explanations of the existence and boundaries of firms in which the definition of a firm is based upon authority relations are challenged by the above arguments. For a discussion of this, see Foss (2002).

decides whether to accept employment or not. In this period, none of the parties know which actions will be optimal, given circumstances. In the next period, the relevant circumstances as well as the costs and benefits associated with the various possible tasks are revealed to the boss. The boss then directs the worker to a task, which — for the latter to accept the assignment — must lie within his or her "zone of acceptance." An important feature of authority thus is that the authority of a superior is constrained by the acceptance of the subordinate of the authority. "A subordinate may be said to accept authority," Simon (1951: 22) explains, "… whenever he permits his behavior to be guided by a decision reached by another, irrespective of his own judgement as to the merits of that decision."[3] Simon's explanation is quite akin to Coase's (1937). In the presence of uncertainty, Coase argues, contingencies are costly to anticipate and describe in advance, and rather than negotiating on a spot market basis over each contingency as they arise, an employment contract is concluded. The latter is defined as "… one whereby the factor, for a certain remuneration (which may be fixed or fluctuating) agrees to obey the directions of an entrepreneur *within certain limits*. The essence of the contract is that it should only state the limits to the powers of the entrepreneur. Within these limits, he can therefore direct the other factors of production" (idem.: 242). Simon and Coase's understanding of authority is summarized in the following definition:

> **Definition — Type I Authority:** *Authority is a right to decide that an employer acquires, because he expects to obtain only ex post contracting the relevant information that will make possible the picking of efficient actions, which he will then direct the employee to carry out.*

This notion is based on the employer picking well-defined actions from a set of discrete actions (about which the employer has perfect information). He does this on the basis of knowledge that is superior to that of the employee. Thus, under this definition the employer grants no discretion with respect to the choice of actions. However, as Simon (1991: 31) himself pointed out four decades after his paper on authority, "[a]uthority in organizations is not used exclusively, or even mainly, to command specific actions." Instead, he explains, it is a command that takes the form of a result to be produced, a principle to be applied, or goal constraints, so that "[o]nly the end goal has been supplied by the command, and not the method of reaching it."[4] This does *not* presuppose that the employer is as knowledgeable as the employee about how to best carry out a task. An important difference relative to Simon's earlier definition is that this notion of authority allows for the delegation of discretion.

Discretion is granted to employees for a number of reasons, including economizing with principals' opportunity costs (Salanié 1997), improving motivation through "empowerment" (Conger and Canungo 1988), fostering learning by providing more room for local explorative efforts and improving collective decision-making by letting more

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[3] In contrast, in a market contract, the parties negotiate *ex ante* about the actions that the agent can take in response to various contingencies so as to fulfill the contract. Thus, the principal's flexibility under market contracting is limited compared to what it would be under authority.

[4] In fairness to Simon, it should be noted that the more expansive notion of authority in the 1991 paper can be found already in Simon (1947). Thus, Simon's views of authority did not change between 1951 and 1991. What arguably happened was that Simon in the 1951 paper developed a formal model of authority and that tractability of the formal analysis required that a relatively simple concept of authority be employed.

employees have an influence on decisions (Miller 1992). Importantly, delegation also allows for the use of distributed knowledge in firms (Jensen and Meckling 1992).

There is also a cost side to delegation. This brings a further function of authority into focus, namely to constrain "the method[s] of reaching" an end goal, in Simon's (1991) terminology. In Simon (1951), the only restrictions in employment contracts are those that are placed on the use of authority by the *employer* (i.e., the notion of "zones of acceptance"). However, the decision rights that are granted to employees are in actuality constrained in various ways. Also, top-management keeps ultimately decision rights, so that it can overrule decisions made on the basis of delegated decision rights (Baker et al. 1999).

Because delegation is exercised in the context of a firm — hence, employees are not full owners or residual claimants on the results of their decisions, and do not share all relevant knowledge —, delegation unavoidably produces spillover effects (i.e., "externalities"). These may be harmful to firm performance. The relevant externalities include, but are by no means limited to, morally hazardous behavior (Holmström 1979; Holmström and Milgrom 1991). They also include coordination failures, such as scheduling problems, duplicative efforts (e.g., of information gathering, R&D, etc.), cannibalization of product markets and other instances of decentralized actions being inconsistent with the firm's overall aims, etc. One way to reduce such harmful externalities is to constrain decision rights and monitor their use (Fama and Jensen 1983; Holmström and Milgrom 1991). Such monitoring may lead to overruling of decisions made on the basis of delegated rights.

This suggests a rationale for authority that is rather different from the one associated with Type I Authority, namely to delegate and constrain discretion.[5] For example, the right to use an asset in certain ways may be delegated; however, it is understood that this right does not entail the right to use the asset in the service of a competitor firm, nor may the asset be used in a way that management perceives as being damaging to the firm. It is also understood that breaking this understanding will be sanctioned.[6] Setting constraints also implies the rights to veto decisions made on the basis of delegated rights, and to withdraw delegated decision rights (this may be seen as a special case of constraining rights). Given the above, we may put forward a second definition of authority:

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[5] The rather considerable literature on delegation in organizations (e.g., Galbraith 1974; Fama and Jensen 1983; Jensen and Meckling 1992) does not explain why delegation should be associated with the exercise of authority. Part of the reason may lie in the static nature of the analysis: All costs and benefits associated with delegation are given (hence, optimum delegation is known immediately to decision-makers), and there is no role for authority, except than perhaps monitoring the use of delegated decision rights.

[6] Multi-tasking considerations (Holmström and Milgrom 1991) also suggest a basic reason why decision rights may be constrained; thus, agents' attempts to carry out activities that are easily measured and therefore directly rewarded at the expense of harder to measure, but necessary activities may lead to the former ones being curtailed.

Definition — Type II Authority: *Authority is a decision right that an employer acquires, because he expects to obtain only ex post contracting the relevant information that will make possible the efficient delegation of discretion and the constraining of such discretion.*

In this definition, the holder of authority makes choices from a set of alternative possibilities of delegating. He does not necessarily have perfect information about 1) the members of this set, 2) how a given level of delegation maps into possible actions, and 3) the consequences of the relevant actions. Thus, the knowledge demands associated with Type II Authority *are consistent with the exploitation of distributed knowledge*. We think of Type Authority II as a means of coordination in situations where productive problems facing firms need to be defined, decomposed, and adjusted to changing circumstances. In other words, Type II Authority facilitates a firm-wide learning process (Egidi 1992), a theme that we develop in more detail later.

Distributed Knowledge

During the last decade the notion of distributed knowledge has been used more and more frequently as an apt description of the knowledge conditions in which modern firms are increasingly finding themselves.[7] Thus, in the strategy field, Tsoukas (1996) conceptualized the firm as a distributed knowledge system, and Granstrand, Patel and Pavitt (1997) documented the increasing extent to which the knowledge bases controlled by major technology-intensive corporations are distributed. Lessard and Zaheer (1996) discussed the implications of distributed knowledge for decision-making, Hutchins (1995) and Gherardi (1999) discussed its implications for organizational learning, while Cohen and Regan (1996) applied the notion to technology management, Foss (1999) discussed its implications for the modern economics of organization, and Larsen (2001) applied it to knowledge-intensive service firms. Apparently, the notion rings a bell in a number of diverse contexts. But what does it mean to say that knowledge is distributed? Unfortunately, the above contributions are not entirely forthcoming with respect to precise definitions of this concept.

Distributed knowledge is a member of a set of concepts that relate to the different ways in which knowledge may "belong" to a group of agents. Two other examples of this kind of concepts are the game theory notion of "common knowledge" and "shared knowledge." An event is common knowledge among a group of players if each player knows it, each one knows that the other players know it, each player knows that other players know that the other players know it and so on (Aumann 1976).[8] Shared knowledge differs from common knowledge by not requiring that each agent knows that the other agents know, etc. Thus, there is shared knowledge of a fact if each agent knows this fact, but does not know that the other agents know it.

If common knowledge lies at one end of the spectrum, distributed knowledge lies

[7] To our knowledge, the term originates with Halpern and Moses (1990). However, the basic idea has a much longer pre-history, not only in the logic of knowledge, but also in political philosophy (e.g., Hayek 1945, 1973).

[8] Common knowledge is a core assumption in contract theory, including agency theory (Salanié 1997).

at the other end. Loosely, knowledge is distributed when a set of agents knows something no single agent (completely) knows. Thus, the notions that firms (Tsoukas 1996) or industrial districts (Foss and Eriksen 1995) or whole economies (Hayek 1945, 1973) are distributed knowledge systems mean that the set of agents comprising these entities collectively possesses knowledge that no single agent possesses. Note that this does not amount to asserting the existence of mysterious supra-individual "collective minds." Knowledge still ultimately resides in the heads of individuals; however, when this knowledge is combined and "aggregated" in certain ways, it means that considered as a system, a set of agents possesses knowledge that they do not possess if separated. Epistemic logic (Hintikka 1962) allows for a definition of distributed knowledge:

> **Definition — Distributed Knowledge:** *If $K_i p_i$ means that agent i knows proposition i, a set of n agents has distributed knowledge of a proposition q (i.e., Dq) when: $K_1 p_1 \wedge K_2 p_2 \wedge \ldots \wedge K_n p_n \Rightarrow Dq,\ q \neq p_i,\ \forall i$.*[9]

For example, Jack knows that p is the case and Jill knows that p implies y, but neither know that y is the case. However, if Jack and Jill's information states are "added" there is a sense, which is more than metaphorical, in which they may know that y is the case (Gerbrandy 1998: 53). The information that y is the case is present in the system comprising Jack and Jill, but in a distributed form.

The above definition is open to some interpretation. At one extreme, Jack and Jill may both be completely ignorant about the knowledge controlled by the other party. Sometimes such an interpretation is made of the "competitive equilibrium" model in economics: Although knowledge of technologies and preferences is private, all this knowledge is utilized in the best possible way, so that the knowledge of how to bring about an allocation of resources with superior welfare properties is distributed in the economy (Makowski and Ostroy 2001). At the other extreme, there is considerable, but not complete,[10] knowledge overlap (p_i may be close in some sense to p_j), but it is still the case that no single agent knows q. Between the extremes are different degrees of overlap between individual knowledge elements.

Intentional Coordination of Distributed Knowledge

It is hard to imagine that coordination of distributed knowledge may take place in the complete absence of some knowledge overlap. Even under the pure form of market coordination (i.e., competitive equilibrium) some knowledge overlap has to be present. Trivially, all agents have to understand the meaning of prices, and to know the set of available goods. Still, the market system is the primary example of unintentional coordination in the face of distributed knowledge (Hayek 1945) (cf. Hayek's notion of "spontaneous order," Hayek 1973). Other mechanisms, such as routines (Nelson and Winter 1982), and common knowledge (Cremer 1990, 1993; Foss 2001), may also help to achieve spontaneous coordination in the face of distributed knowledge.

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[9] p_i could be interpreted as a vector of propositions. Thus, we are not asserting that each agent only knows one thing.

[10] If knowledge overlap is complete, the agents will also know or be able to infer q (if they have perfect rationality/perfect reasoning assumptions and/or the knowledge elements and how they connect is easy to comprehend).

However, note that it is not in conflict with the above definition of distributed knowledge to have some agent — that may be called a "coordinator" — possessing the knowledge that if Jack and Jill's knowledge sets are somehow aggregated, this will result in their having, as a "system," a knowledge that none of them possesses individually. The coordinator does not need to know that Jack knows that p is the case and Jill knows that p implies y. However, she does need to know that there is a set P of which p is a member and that these elements map to certain outcomes, Y, of which y is a member. Thus, although the coordinator may still be ignorant in an important sense about the knowledge controlled by Jack and Jill, she does not suffer from complete ignorance[11]; there is some, possibly very modest, knowledge overlap. She may therefore be able to pass judgement on the overall abilities of Jack and Jill, and, in particular, about how actions based on Jack and Jill's knowledge may be coordinated. In other words, it is possible to have knowledge of interdependencies between actions based on different knowledge elements without possessing much knowledge of these elements themselves (see also Spangler and Peters 2001).[12]

An illustration of the notion that such "systemic" knowledge can be had without necessarily having (much) knowledge of individual knowledge elements may be found in the theory and practice of software development. Thus, Parnas (1972) develops the notion of "information hiding," a notion that refers to the desirability in software development (particularly in major projects) of literally hiding information in decomposed modules and so bring interdependencies down to the absolute minimum. Individual programmers ideally (!) should have very little idea about what is going on in the other modules. The development effort is thus of a distributed nature. Still, it has to be steered, notably by the design of an architecture, interfaces and standards. The coordinator has to design these — define a decomposition of the overall development problem — without being cognizant about much of what goes on in individual modules. In actual practice, this means that the design of the architecture, interfaces and standards is very much a trial-and-error learning process (e.g., Staudenmeyer and Cusumano 1998), what Egidi (1992) calls "conjectural decomposition."[13] Note in passing that such conjectural decomposition appears to predominantly within firms rather than in market relations.

Changing Distributed Knowledge

Many writers argue that distributed knowledge conditions have become increasingly important in modern competitive conditions, as firms to a greater extent

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[11] On the other hand, it may not be entirely correct to say that she is "asymmetrically informed." In asymmetric information models, such as agency models, an agent knows precisely what she is ignorant about (e.g., the probability distribution associated with quality levels of a good). No such strong knowledge requirements are assumed here; only that the coordinator can pass judgment on the capacities of individual agents and on how their efforts may be aggregated into some coherent outcome.

[12] Discussing leadership in the context of new organizational forms, Zenger (2002: 91) notes that "[s]uch leadership requires at a minimum cognizance of the patterns of complementarity that support organizational forms and influence common change initiatives."

[13] Major product development projects that involve the problem-solving efforts of highly interdependent teams with distributed knowledge are usually based on such conjectural decomposition. Recent examples include the Boeing 777 development effort as well as Microsoft Windows (Cusumano 1997).

need to access an expanding set of external knowledge sources (Coombs and Metcalfe 2000; Smith 2000; Arora and Gambardella 1994), and increasingly need to rely on specialist knowledge controlled and accumulated by specialist employees (Miles et al. 1997). There is nothing new *per se* in the notion that knowledge for productive purposes may be distributed; indeed, it is a necessary consequence of the division of labor and bounded rationality (Hayek 1945, 1973; March and Simon 1958; Arora and Gambardella 1994). Rather, what is being asserted by a number of authors seems to be that there are significant discontinuities in the evolution of distributed knowledge, so that the distributed character of knowledge has strongly increased during the last decades. Thus, Granstrand, Patel and Pavitt (1997) document the significantly increasing extent to which firms organize in-house distributed technological knowledge, drawn from an growing number of underlying technological disciplines. Wang and von Tunzelman (2000) emphasize that not only are the number of disciplines that firms draw on expanding, it is also the case that these disciplines themselves evolve in terms of their depth and specialization; firms' sourcing of technological knowledge reflects this.

These observations and the above definition help us to better understand what it means to argue that "knowledge is becoming more distributed." Thus, we may say that knowledge becomes more distributed when

1. n (i.e., the number of agents and propositions/knowledge elements) increases (cf. Granstrand, Patel and Pavitt 1997); and/or
2. The overlap between individual knowledge elements is reduced. Knowledge overlap may be reduced for two principal reasons:

   2A. One (or more) knowledge element that was known by j ($\leq$ n) agents are now only known by h ($<$ j) agents. Thus, forgetfullnes in this sense makes knowledge more distributed. Changing from a state with less division of labour to one with more may exemplify this, because each agent needs to control less different knowledge under more division of labour; and/or

   2B. Knowledge elements/propositions become more heterogeneous (cf. Wang and von Tunzelman 2000). For example, whereas in an initial period, a firm draws all its production knowledge elements from the engineering discipline, in a later period it adds knowledge elements drawn from the discipline of chemistry; or
3. Some mix of the above obtains.

We next turn to the argument that the increasingly distributed nature of knowledge in the sense discussed above means that authority is becoming inefficient as a mechanism of coordination.

Distributed Knowledge as a Challenge to Authority

The first systematic argument that distributed knowledge represents a challenge to central planning and direction was developed by Friedrich Hayek (1935, 1945) in the specific context of the interwar debate on the economic efficiency of socialism (see Lavoie 1985). In a famous passage (Hayek 1945: 77-78), he notes that

> [t]he economic problem of society is … not merely a problem of how to allocate "given" resources – if "given" is taken to mean given to a single mind which

> deliberately solves the problem set by these 'data.' It is rather a problem of how to secure the best use of resources known to any of the members of society, for ends whose relative importance only these individuals know. Or, to put it briefly, it is a problem of the utilization of knowledge which is not given to anyone in its totality.

The problem is aggravated by the fact that much of the important knowledge is tacit, fleeting and subjectively held. Hayek further argues that since centralized planning is fundamentally inefficient in the face of distributed knowledge, our understanding of how social systems cope with distributed knowledge must shift to alternative mechanisms, in particular those mechanisms characterizing marked-based, "great societies" (Hayek 1973), that is, the price system, the private property rights structure, the rule of law, and a morality that is conducive to market organization. To update Hayek somewhat, it may be argued that as socialist central planning has been abandoned in most of the World, coping with the problem posed by distributed knowledge has moved from being a problem for socialist planners to increasingly being a challenge confronted by firms in capitalist economies, as distributed knowledge allegedly clash with hierarchies and firm planning.

In his early works, Hayek (1935, 1945) does not directly criticize the use of authority as a mechanism of coordination; rather, his critical target is the notion that benevolent planners can draft complete contingent plans for the allocation of resources on a societal level, based on all relevant knowledge being concentrated in the hands of a central planner. However, in a later contribution, he points to a central "… problem which any attempt to bring order into complex human activities meets: the organizer must wish the individuals who are to cooperate to make use of knowledge that he himself does not possess" (Hayek 1973: 49). Although Hayek does not resolve the problem, he admits that it is, in fact, solved, more or less, efficiently on an everyday basis, notably in the form of the exercise of authority in large-scale organizations, including large firms.

Although there is a striking parallel between Hayek's arguments, and those put forward by modern scholars, Hayek does not say that the "problem" cannot be solved. This is in contrast to what is being argued by modern scholars. Thus, Grandori (1997: 35) argues that "… whatever its basis, authority is a feasible governance mechanism only if information and competence relevant to solving economic action problems can be transferred to and handled by a single actor, a positive "zone of acceptance" exists, the actions of other supervised actors are observable, and if the system is not as large as to incur an overwhelming communication channel overload and control losses." According to this argument, distributed knowledge challenges authority because it implies that all "information and competence" relevant to solving a problem cannot be given to a single decision-maker, actions are not generally observable, and there may be substantial "communication channel overload and control losses" — all problems highlighted by Hayek.

To be more specific, we interpret the argument as follows. The challenge to authority as a "feasible governance mechanism" arise for three basic reasons: Under distributed knowledge, 1) the employer does not possess full knowledge of the

employee's action set (i.e., the actions that he can take when uncertainty is resolved), so that the employee can take actions about which the manager has no knowledge; 2) the employee is better informed than the employer with respect to how certain actions should (optimally) be carried out; and 3) the employer does not know which actions should optimally be chosen from the action set in response to contingencies (because he lacks information on contingencies). The sheer ignorance on the part of directing employers that is implied by 1) to 3) then means that authority cannot be an efficient mechanism of coordination. The growing knowledge-intensity of production, requiring increased reliance on knowledge specialists, as well as the growing need to source multiple knowledge sources (implying that knowledge is becoming increasingly distributed), mean that 1) to 3) are becoming increasingly accurate in a descriptive sense, so that authority is being challenged as an efficient mechanism of coordination. In the following, we discuss the extent to which the argument thus interpreted challenge Type I and Type II Authority.[14]

Authority in the Context of Distributed Knowledge

In this section, we discuss whether authority (of the two types considered earlier) may exist as efficient mechanisms of coordination under distributed knowledge, and, if so, what are the limits to the exercise of authority under distributed knowledge. Our strategy is to examine the means (i.e., coordination mechanisms) through which knowledge that is distributed in a group is aggregated. We first discuss Type I Authority as a coordination mechanism under distributed knowledge. We then develop the point that the coordination problem in a situation of distributed knowledge depends very much on the nature of the problem to which the relevant knowledge is applied as a means of creating solutions. Our reasoning is cast in the context of a problem-solving approach derived from Simon (1962, 1973).[15] This allows us to analyze the use of Type II Authority under distributed knowledge conditions.

Type I Authority Under Distributed Knowledge

A problematic feature of Type I Authority is that it assumes that, in Weberian (Weber 1947) terminology, "authority of the office" and "expert authority" coincide. Under distributed knowledge this cannot generally be the case. However, the

[14] Distributed knowledge challenges authority in a way that we shall not discuss extensively, namely by making problematic the sources of authority, particularly the idea that these sources are found in ownership of alienable assets (Hart 1996). Distributed knowledge is arguably associated with "expert authority" (Zucker 1991). This is because distributed knowledge is a product of the division of labor. In turn, increasing the division of labor implies an increase of knowledge specialization (Hayek 1945), which, at least temporarily, means that some specialists may possess a scarce and costly-to-copy knowledge advantage that may give them considerable bargaining power. It is hard to exercise ownership-based authority over such specialists, because they posses bargaining power that "offsets" ownership-based authority. For a discussion of this point, see Foss (2002).

[15] A number of writers have, explicitly or implicitly, argued that governance choice is dependent on the characteristics of problems (and their corresponding solution landscapes) (e.g., Loasby 1976; Brusoni, Principe and Pavitt 2001; Langlois 2001; Nickerson and Zenger 2002). We extend this focus to coordination mechanisms.

argument that this means that Type I Authority is inherently inefficient is a *non sequitur*. This is because the argument implicitly takes it for granted that suppressing distributed knowledge must always be inefficient. Under distributed knowledge conditions it may well be the case that the benefits from the exercise of "authority of the office" may overwhelm the costs from suppressing "expert authority."

This may be the case in situations when urgent, coordinated, and simultaneous action is required in a system with highly complementary elements (e.g., actions), notably because an equilibrium is upset by the emergence of some unexpected contingency and it is necessary to home in on a new equilibrium or the old one. The relevant tradeoff is between making use of distributed knowledge and reacting in a timely manner (Bolton and Farrell 1990). While communication between the agents may make use of all distributed knowledge, communication is also time-consuming. Since contracting necessitates communication, it is also suffers in terms of time costs. Moreover, since what is being faced is a new situation, relevant routines for coordinating adaptation have not been established. Using the price system for the purposes of coordination is ruled out by the characteristics of the situation (Milgrom and Roberts 1992: chapter 4). The implication is that "decisions are best managed in a centralized way" (idem.: 115), that is, by the use of authority, even though management may be ignorant about much of the knowledge that is potentially relevant to the problem.

Similarly, Hammond and Miller (1985: 1) argue that "… knowledge about any particular problem is seldom complete, and in a competitive or changing environment there may be advantages to making *some* decision, however imperfectly grounded on expertise, rather than none at all … In the absence of expert knowledge some chief executive is given authority to impose his own best judgment on the matter."In our view these are compelling arguments. They accord well with our earlier argument that a coordinator (here: management) may have some rational basis for exercising authority, even in the narrow sense of Type I Authority. However, this rationale for authority is arguably somewhat limited. Thus, if contingencies that give rise to situations requiring urgent decision-making in systems arise frequently and/or regularly, responses to these contingencies can be routinized (Kreps 1990). This suggests the following proposition:

> **Proposition 1**: *Under distributed knowledge, the efficient exercise of Type I Authority takes place in situations where actions are complementary, and where simultaneous adaptation to an unexpected contingency is urgently required.*

Although it is thus possible to find a role for authority under distributed knowledge, that role is quite limited if by "authority" is understood Type I Authority. However, we made the point that authority needs to be seen in a broader perspective, and developed the notion of Type II Authority. As we argue the function of Type II Authority is best understood within a problem-solving perspective on organizations.

A Problem-Solving Perspective

A starting point for thinking about the organization of problem-solving in the context of distributed knowledge is provided by Simon (1962).[16] "In hierarchic systems," Simon (1962: 473) explains, "… we can distinguish between the interactions *among* subsystems on the one hand, and the interactions *within* subsystems – i.e., among the parts of those subsystems – on the other." This forms the basis for a distinction between *decomposable* systems, in which the interactions among the subsystems are negligible; *non-decomposable* systems, in which the interactions among the subsystems are essential; and *nearly decomposable* systems, in which the interactions among the subsystems are weak, but not negligible (1962: 129). Simon also explains that an important aspect of what makes the social and natural world comprehensible is that they often involve phenomena that may be represented as nearly decomposable hierarchies; for example, "[s]ubparts belonging to different parts only interact in an aggregative fashion – the detail of their interaction can be ignored" (1962: 477). We can understand the system exactly because we can ignore these "details"; if we also had to comprehend the details it would be "beyond our capacities of memory and computation" (ibid.) to understand the full system.

In other words, the epistemological problem of comprehending a complex system is eased when the system is decomposable or nearly decomposable (see also Loasby 1976). The implication is that problem-solving may proceed by means of decomposing problems into sub-problems, and that there may be certain advantages to such an approach.[17] One of the advantages of decomposing problems is that it reduces the exchange of information (costs of coordination) between agents relative to a situation where problems are not decomposed (to the same extent). This is relevant in cases where not all knowledge is commonly held, that is, in cases where some knowledge is shared or distributed. In fact, the decomposition of problems promotes the application (and growth) of specialized knowledge that may be distributed among different agents. This is because with decomposable or nearly decomposable problems, agents can relatively independently apply distributed knowledge elements to sub-problem solutions. Moreover, the relative independence between sub-problems limits the need for exchange of information between agents working on these various sub-problems, implying a small need for shared knowledge elements between agents.

This would indeed seem to point to a limited role for authority in situations where problems are decomposable or nearly decomposable. However, an important aspect of the "aggregation of distributed knowledge elements" into a coherent solution to a problem is the creation of a problem architecture, that is, the specification of sub-problems and of the patterns of interaction that are needed to resolve the remaining interdependencies between sub-problems. As we shall argue in the next section, when problems are complex, creating an architecture is likely to take place through trial-and-

[16] The association of problem-solving with organizations and the authority relations they embody is a well-known theme in organizational theory (Simon 1947; March and Simon 1958; Loasby 1976; Mintzberg, Raisinghani and Théorêt 1976; Marengo 1995; Garicano 2000; Nickerson and Zenger 2002).

[17] Simon's famous story of the two watchmakers, Tempus and Hora, and their entirely different ways of making watches, one modular and one integral, exemplifies this idea.

error processes. Such processes may be directed to some extent or they may be blind. In the case of nearly decomposable problems, creating an architecture may require directed trial-and-error. Authority may be the least-cost mechanism for directing such trial-and-error processes.

The Role of Authority in the Creation of Problem Architectures

A first step in the creation of a problem architecture is the decomposition of a problem. However, this requires that the problem has been *made* well-defined. In fact, Simon (1973: 186) forcefully argues that virtually all problems presented to problem solvers are, from the outset,

> … best regarded as ill structured problems. They become well structured problems only in the process of being prepared for the problem solvers. It is not exaggerating much to say that there are no well structured problems, only ill-structured problems that have been formalized for problem solvers.

Thus, well-structured problems are outcomes of *deliberate* problem-defining processes. Defining a problem requires that constraints are imposed on it. Simon (1973) provides several examples of problems (relating to shipbuilding and building a house) that are initially extremely ill-structured, but which through the imposition of constraints become well-structured. A key point in his discussion is that initial choices of constraints define the major interdependencies in the problem-solving effort, in the sense that these constraints define what are the (first levels of) sub-problems and the relations between these. Moreover, the kind of constraints that is chosen will to some extent influence whether problems can be fully decomposed, nearly decomposed or not decomposed at all.

Setting constraints is thus an important aspect of the creation of a problem architecture. In some cases, it requires experience, expert knowledge or entrepreneurial insight to set these constraints in a manner that makes problem-solving feasible and effective. Simon (1973: 191) clearly hints at this in his discussion of an architect setting up what is in effect a problem-solving organization for the task of building a house. As he notes, part of the architect's "… professional training and subsequent learning is directed to organizing the process in such a way that the major interactions among components will be taken care of." Note that an architect has to coordinate in the presence of distributed knowledge; there are numerous knowledge elements that he will have no or very little knowledge about.

Thus, setting the constraints often require a different kind of knowledge compared to that which is needed to solve the various sub-problems. Now, setting constraints may be an ongoing process, because, as Simon (1973: 189) notes (quoting Reitman 1965: 169), "[o]ne of the interesting features of many of the problem instances … is that even though they generally would be considered complex, they include very few constraints as given. Composing a fugue is a good example. Here the main initial constraint, and it is an open constraint at that, is that the end product be a fugue. All other constraints are in a sense supplementary, generated from one transformation of the problem to the next." In other words, problem-solving is a path-dependent process — one that may evoke different knowledge elements and require different kinds of intentional actions of

agents at many levels in the creation of the problem architecture.

To sum up, problem-solving is a process that involves both the setting of the constraints for the effort, and the decomposition of problems into sub-problems. Not all constraints can be defined initially, and new constraints (around new sub-problems) arise endogeneously in the process. All this provides a role for deliberate problem-solving, and the use of experts in problem definition. They may need to posses some knowledge of the problem, although this knowledge need not be completely common or even shared among agents participating in the problem-solving activities. However, in the process of problem-solving, unexpected interdependencies between sub-problems are bound to arise, requiring *coordinated* problem-solving. The necessity of iteration between sub-problems and succeeding design changes, follow from the impossibility of getting the decomposition right initially (cf. Simon 1973: 191). The following quotation from a software developer is illustrative:

> A lot of time people don't realize that they are dependent on something. It's just not obvious. For example, you don't realize that you have a dependency because you are not familiar with that part of the code. Or a dependency just sort of materializes out of thin air because of a need and is tracked informally. Or instances where the solution to one dependency creates problems for a third party. The real problems with the hidden interdependencies – the ones that no one thought about pop up at the last minute" (quoted by Staudenmeyer and Cusumano 1998: 18-19).

The developer goes on to stress the need for carefully managing the process of iteration. When problems are only nearly decomposable such management often mimics a controlled experiment in which all connected developments efforts, except for a few whose exact links need to be further investigated, are halted. The use of such controlled experiments can be made more effective if it is steered by agents who have knowledge of the possible linkages between sub-problems, without necessarily knowing all the details needed to carry out each of the experiments.

So far we have argued that the creation of a problem architecture is made more effective if expert knowledge is brought to bear on the definition of the architecture and on the management of whatever interdependencies remain after the decomposition. The experts needed in the process of defining the problem architecture need not posses the same knowledge as those who solve the sub-problems. In other words, the definition of the problem architecture does not require totally common or shared knowledge; thus, there would seem to be ample room for the application of distributed knowledge in problem-solving. However, some elements of shared knowledge between those who solve sub-problems and those who create the problem-solving architecture may be required in order to create effective problem solving architectures. This still leaves unanswered the question of why authority is needed in the problem-solving process. We address this in the following.

Comparative Analysis

As has been argued, problem-solving is often an ongoing process in which constraints are refined or changed and sub-problems and their interdependencies are

discovered. A problem architecture emerges from such a process, one that will only need to be changed if for some reason it becomes apparent that the problem should be structured differently or if major unforeseen interdependencies emerge as sub-problems are solved. The effective creation of a problem architecture may require the use of experts, but not necessarily the use of authority, since the advice of experts in the creation of problem architectures can be purchased (Coase 1937).[18] In fact, one may imagine the organizational design to be a good that a team of independent problem-solving agents purchases in a market from a specialist in developing such designs. The team will then simply implement the design.

The issue of the use of authority arise with respect to how the residual interdependencies as defined in the problem architecture are to be managed. In turn, this depends on the nature of these interdependencies. If the problem is already decomposed, and only sequential interdependencies remain between sub-problems (Thompson 1967), adaptation to unexpected contingencies may be handled through, for example, prices, routines, standards, the use of kanban methods, etc. With Sequential interdependencies Information then only need to travel one direction to ensure adaptation between problem-solving activities and agreements on adaptation only needs to be reached between agents engaged in adjacent activities since that is where externalities emerge. Modular production systems exemplify this (Langlois 2002).

If instead the remaining interdependencies are of a reciprocal kind, these may be handled by means of communication between the team members and possible disagreements may be handled by outside arbitration. However, when nearly decomposable problems contain complex interdependencies between sub-problems, the costs of mutual adaptation through consultation (i.e., lateral communication) and/or negotiations among the agents working on the sub-problems may be very high. In such instances the costs of mutual adaptation compared to the costs of making use of some type of directions may outweigh the benefits in terms of the use of the distributed expert knowledge. In particular, this may be the case if one or more agents have expert knowledge with respect to what are the effective adaptations or on how to carry out controlled experiments that will reveal effective means of adaptation. This leaves room for the use of Type I or Type II Authority, although even adaptation in the face of complex interdependencies may in time be carried out on a routine basis.

However, some problem-solving has an ongoing character, as when organizations are set up to design, produce and sell various types of goods. In such instances, the exact definition and decomposition of the problem of designing, producing and selling a good may have to change over time as the agents involved learn more about the interdependencies involved in solving the problem, as outside contingencies change, or as agents discover new ways of setting constraint on the problem. It is with respect to such situations that Type II Authority is an important means of creating and recreating problem-solving architectures, particularly when problems are nearly-decomposable or non-decomposable.

[18] Market exists for expert advice, although such advice as an economic good suffers from the well known problems in connection with markets for information.

The task of authority in the context of non- or nearly-decomposable problems is to create the organization that matches the problem solving architecture and to adapt it to changes in the definition of the problem and to changes in outside contingencies. This implies the creation of job descriptions (sub-divisions of tasks) delegating the right to further subdivide sub-problems and establish information linkages and/or incentives that will allow actions taken on the bases of distributed knowledge to be aggregated in way that minimize negative externalities.[19] This implies that the organizational design process should essentially be seen as an ongoing learning process, particularly in complex firms that are placed in dynamic environments, so that the organization design task is a recurrent one (Egidi 1992). It is in those instances that it is efficient for a manager to acquire the right from an employee to delegate discretion and constrain such discretion as he obtains ex post contracting the information that make it desirable to re-define and re-decompose problems — that is, to obtain Type II Authority.

The use of Type II Authority in the context of an employment contract is efficient relative to spot-market contracting, since the use of markets would require costly re-contracting as the relevant information was revealed (Coase 1937; Egidi 1992). This leaves the use of type II Authority and the employment contract to be compared to that of relational contracting between independent agents. Relational contracting differ from spot market contracting in the fact that much more emphasis is placed on maintaining the relation between agents even when non-foreseen adaptations in the relationship is required. Such adaptation may be undertaken based on a proposal from one or more agents, on consultation between agents, or on the initiative of one or more agents. Negotiations and side payments among the agents may be one means of implementing changes, but the use of voting or other procedures may also be used. In relational contracting, the circumstances under which adaptation is needed, as well as the procedure to be used in reaching an agreement, are specified in a contract. Thus, some agreement has to be reached *ex ante* with respect to the future needs for adaptation, and on the procedure through which agreements on adaptive actions are to be reached. This is where relational contracting differs from the use of authority. Although authority can only be exercised within the limits of the zone of acceptance of employees, this may still leave the contracting parties with much greater room for low cost adaptation, because there is no need to renegotiate the contract.

To best exploit distributed knowledge, discretion should be delegated to those who have a comparative advantage in solving the relevant (sub-)problems. The hierarchical nature of problem solving implies that the person in the top can undertake organizational design tasks in the presence of distributed knowledge. She can undertake the major decompositions without necessarily knowing the specific interdependencies between sub-problems. She can also allocate discretion to subordinates without necessarily knowing their complete sets of actions and capabilities, as long as she can pass judgment on their comparative advantages with

[19] Given the uncertain nature of the process, the process of decomposition will almost certainly be one of trial and error (Egidi 2002). Grandori (1997: 37) notes that it has been "well-documented" in organization studies that "… authority is not very effective in managing uncertainty." The arguments developed here imply rather the opposite.

respect to solving certain types of sub-problems. Thus, delegating and constraining decisions, that is, exercising Type II Authority, is entirely consistent with distributed knowledge. As argued above it may even be a preferred means of coordinating problem-solving. This reasoning suggests the following proposition:

> **Proposition 2:** *In terms of efficiency, Type II Authority dominates alternative mechanisms of coordinating problem-solving efforts under distributed knowledge when near-decomposable problems are characterized by complex interdependencies and when problem-solving have an ongoing character. The efficiency of the use of authority increases relative to the use of consultation as agents improve their comparative advantages in coordinating distributed knowledge, as costs of communication increases, and as the costs of reaching an agreement on adaptive actions (or on the procedures to be used) increase.*

The Use of Type II Authority When Knowledge Becomes Increasingly Distributed

When knowledge is distributed among a group of agents, per definition none of the individual agents possess the complete set of knowledge. Since agents act on the basis of local knowledge, rather than on the basis of complete knowledge, they may have a hard time comprehending overall goals implied by the complete knowledge. Moreover, in the case of interdependencies between their actions, they may have a hard time identifying and evaluating the externalities that emerge from their interaction. In fact, the more distributed the knowledge becomes (e.g., there are fewer elements of shared knowledge), the higher the costs of communication and the costs of identifying externalities that arise from interdependencies in problem-solving. Finally, the more distributed the knowledge, the harder it may be to reach agreements on efficient adaptive actions or to create procedures that satisfy all the agents involved in the problems-solving.[20] These arguments suggest that increasingly distributed knowledge pulls in the direction of greater use of authority.

However, increasingly distributed knowledge may also have a negative impact on authority. This is particularly so if the distributed knowledge elements that enter into the overall solution that an organization is set up to reach are drawn from increasingly different bodies of knowledge. This implies that it becomes more difficult to find agents who posses sufficient knowledge in the relevant fields that enable them to set the efficient constraints on problems and to undertake the initial decomposition of the problem — that is, agents with a comparative advantage in exercising authority.

The use of authority will be particularly problematic when increasingly different bodies of knowledge in problem solutions inhibits an effective setting of the *basic* constraints and definition of sub-problems. This is because at the top level of the problem-solving hierarchy, constraints and initial sub-problem definition influence the way in which all subsequent levels in the problem solving hierarchy develops. At lower levels of the problem-solving hierarchy, the effect of not being able to define sub-problems optimally has only local effects. Moreover, since the effects on sub-problems have a much more local nature, it enables the use of consultation and overlapping

[20] For example, the use of voting systems may be subject to problems when knowledge of the alternatives are not shared, and negotiations and side-payments may be difficult to execute when knowledge about externalities are not shared.

problem-solving in the process of setting constraints and defining sub-problems.[21] Finally, at the lower levels of the problem-solving hierarchy, it is more likely that sub-problems may then be define in ways that correspond to the use of different bodies of knowledge. The above reasoning suggests the following proposition:

> **Proposition 3:** *In terms of efficiency, Type II Authority will increasingly dominate alternative mechanisms of coordinating problem-solving efforts under increasingly distributed knowledge when 1) knowledge is becoming distributed because more knowledge elements enter into the solution to well defined problem, or 2) when there is less shared knowledge among agents engaged in problem-solving. However, if knowledge becomes more distributed in the sense that knowledge elements are rooted in increasingly different bodies of knowledge, authority will become less efficient.*

Efficient Alignment

Proposition 2 suggests that the efficient choice of authority as a coordination mechanism is dependent on the *characteristics of problems* into which distributed knowledge enter. Proposition 3 suggests that the efficient choice of authority as a coordination mechanism is dependent on *how knowledge is distributed,* in particular how much distributed knowledge elements are overlapping. In other words, our reasoning so far suggests that the efficient alignment of activities to coordination mechanisms depends on the two dimensions of problem characteristics and (distributed) knowledge characteristics. Figure 1 tentatively maps such an efficient alignment framework.

XXXXXXXX *Insert Figure 1 Here* XXXXXXXX

The framework assumes that problems are well structured and have been decomposed in ways that minimize the remaining interdependencies between sub-problems. Thus, the remaining coordination problems refer to the handling of residual interdependencies. We discuss how the two dimensions influence the choice of coordination mechanisms, beginning with problem-characteristics while holding constant the distributed'ness of knowledge.

Problem-characteristics and the choice of coordination mechanisms. In the extreme situation of completely decomposed problems, there are no or almost no residual interdependencies; the coordination task can be undertaken by pricing and/or rules/routines. Modular production systems with fixed interfaces exemplify such systems. Since there is virtually no need for communication and externalities are absent, knowledge characteristics (i.e., the degree of distributed'ness of knowledge) will not influence the choice of mechanisms. In this situation, authority fails for the reasons outlined by Hayek (1945) and echoed by modern writers (Grandori 2002), that is, the losses from suppressing local information (i.e., distributed knowledge) are not compensated by corresponding gains in terms of improved coordination.

At the other extreme we have problems that are completely non-decomposed so that all problem-solving activities are interdependent. Such problems will have to be solved either through consultation that eliminates the distributed character of

[21] This procedure is widely used in product development as a means of making use of distributed and different bodies of knowledge such as marketing and engineering knowledge in product design.

knowledge (i.e., making knowledge shared or common) or through the exercise of authority so that a particular decomposition is conjecturally imposed on the problem. Software development often exemplifies this (Staudenmayer and Cusumano 1998). A mix of authority and consultation will be chosen as mechanisms to coordinate the problem-solving process.

In between these extremes are nearly-decomposed problems which manifest some residual interdependencies between problem-solving activities. These interdependencies may be sequential, bilateral or complex (Thompson 1967). As mentioned earlier, such interdependencies may be handled through many different coordination mechanisms, the choice of mechanism depending on the nature of the interdependencies. Thus, if interdependencies are only *sequential* and externalities arise only between adjacent problem-solving activities, coordination may take place using prices, transmission of other information than prices, routines (if the adaptation is a recurrent one). When interdependencies are *reciprocal*, information about decisions (and/or decision premises) will have to travel back and forth between agents engaged in adjacent problem-solving activities. In this case, consultation between agents may be used and outside arbiters, voting, etc. may handle disagreements. Finally, when interdependencies are *complex,* information will have to travel back and forth between agents engaged in problem-solving in numerous, partly unpredictable ways, so that it becomes much harder for each agent to identify the externalities that arise as a consequence of their problem-solving activities and to agree on adaptive actions. This is where the use of Type I or II Authority is particularly likely to be efficient.[22]

Knowledge overlap and the choice of coordination mechanisms. In the case of completely decomposed problems, changes in how distributed the underlying knowledge is will not affect the choice of coordination mechanisms, since there is only very limited need for communication and there are no or very few externalities.

In the case of non-decomposable problems, increasing (decreasing) overlap of knowledge increases (decreases) the use of consultation (authority), but only to the extent that increasing overlap of individual knowledge elements also imply that agents understand better the structure of the solution and how an optimal solution is best reached.

Finally, in the case of nearly decomposed problems, we again need to consider the nature of interdependencies. Knowledge becoming more distributed implies that more

[22] The problem architectures that characterize well-defined, nearly decomposed problems have all the above interdependencies within and between sub-problems; accordingly, different coordination mechanisms will be applied. However, in the case of ongoing problem-solving, changes in the problem architectures may have to be implemented. This requires changes in the way in which problem solving tasks are defined and information channels and incentives are established. In such instances, Type II Authority may displace the use of other coordination mechanisms. This is most likely to be the case when some agents have expertise in creating problem architectures, and when the problem architecture is mainly characterized by reciprocal, and, in particular, complex interdependencies. With greater interdependencies the costs of mutual communication and agreements increases, making it more efficient to rely on authority.

information will have to be transmitted. As interdependencies change from sequential to reciprocal to complex, the more the relevant problem-solving system will be informationally burdened when knowledge becomes more distributed. This in turn imply less use of prices and more use of consultations. Another consequence of increasingly distributed knowledge is that it becomes more costly for agents to identify the sources of externalities and to agree on corrective actions. As interdependencies change from sequential to reciprocal to complex, the more the relevant problem-solving system will be burdened of the costs of identifying and correcting such costs by means of consultation. This pulls in the direction of more use of Authority Type I and II.

Distributed Knowledge and the Boundaries of Firms

Against the argument that distributed knowledge wrecks havoc with authority, it may be argued that if it were not for distributed knowledge, we would observe much *less* authority. If no knowledge was distributed (i.e., all knowledge existed in common or shared form), coordination problems would be strongly diminished in importance, and there would be very little room for authority (and most other coordination mechanisms). In contrast, under distributed knowledge conditions, the coordination problem of making actions based on individual knowledge elements mesh into a coherent outcome arises. However, this reasoning raises a problem that parallels the Coasian (Coase 1937) problem of why all economic activity is not concentrated in one giant firm when there are "costs of using the price mechanism": If authority has advantages in handling adaptations to unforeseen contingencies in distributed knowledge systems, why aren't all activities in a firm (indeed, in the whole economy) coordinated by means of authority?

We argued earlier that one interpretation of knowledge becoming more distributed is that the number of knowledge elements (e.g., underlying disciplines) that are necessary for producing goods and services increases. Another one is that such knowledge elements become increasingly heterogeneous. The latter interpretation has a long tradition. Thus, Coase (1937) mentions the "dissimilarity of transactions" as one determinant of the boundaries of the firm. Richardson (1972) later argued that firms avoid integrating dissimilar capabilities. The implicit theory behind these arguments seems to be that as knowledge elements become increasingly heterogeneous, the informational basis for the exercise of authority becomes increasingly undermined. Thus, firms will draw their boundaries around capabilities that are "similar" in the terminology of Richardson (1972).

However, a number of recent studies indicate that at the same time that major multi-product firms have narrowed their product portfolios, they have actually increased their underlying technology portfolios (e.g., Granstrand, Patel and Pavitt 1997) and the technological disciplines that constitute these portfolios have become more heterogeneous (Wang and Tunzelman 2000). Relatedly, Brusoni, Prencipe and Pavitt (2001) argue that firms need to control knowledge in excess of what they strictly need for their productive operations. This is because such excess knowledge helps to cope with imbalances caused by uneven development in the technologies they rely on and with unpredictable interdependencies on the level of products. Thus, at least major multi-technology firms seem to control *more* and *increasingly distributed* knowledge within their boundaries, and

subject to the use of the authority mechanism. Thus, it is far from clear how, if at all, distributed knowledge constrains the boundaries of the firm.

A speculative conjecture is that it matters to the boundaries of firms at which *level* of the problem-solving architecture the relevant knowledge is heterogeneous. Arguably, it matters most to firm boundaries if heterogeneity influence or is to be found at the top level of the problem architecture.

Thus, at the top level of the problem architecture, heterogeneous knowledge elements may imply that inconsistent implications can be drawn with respect to the structuring and decomposition of a problem and the way in which interdependencies are to be handled. In such instances it may be better to not make use of some knowledge in order to obtain a greater coherence in problem-definition and problem-solving architecture. The problem is aggravated in the case of distributed knowledge, where agents are specialized in different knowledge domains. For example, agents may believe that if applying their heterogeneous knowledge elements to the problem of defining the initial constraints and sub-problems, the problem can be more efficiently structured and a more efficient problem-solving architecture can be developed. In such instances, any inconsistencies in the implications that can be drawn for the heterogeneous knowledge elements will have to be sorted out and a decision will have to be reached regarding the best way of handling such inconsistencies. Difficulties may arise in such a process, since it is often difficult to identify and evaluate the consequences of the implications drawn from knowledge elements that are unfamiliar to one. When such problems are sufficiently severe, we should expect two firms to exist, each based on different knowledge elements, since the costs of "combining" the knowledge elements may swamp the benefits. If inconsistencies due to heterogeneity of knowledge elements arise at lower levels at the problem-solving hierarchy, the consequences will be less severe, since here unsolved inconsistencies will only have local effects.[23]

However, heterogeneity in knowledge elements at lower levels of the problem architecture may also influence problem solving at higher levels. In some (perhaps most) cases, the creation of an effective problem-solving architecture may require some elements of shared knowledge between those who set the initial constraints and define the initial sub-problems and those who solve the lower-level sub-problems. If knowledge elements that enters into the solutions becomes more heterogeneous there may be fewer elements of shared knowledge between top level problem solvers and lower level problem solvers. This implies that manager lack the meta-knowledge that they apply in aggregating distributed knowledge into a coherent problems solving architecture. Specifically, what constrains the activities that the firm engaged in then is their "coordinative capabilities". From a static perspective, the efficiency of coordinative capabilities with respect to

[23] In some instances, the implications for the creation of a problem architecture drawn from heterogeneous knowledge elements may be fully consistent. In such cases, the main problem may be to find agents with sufficient knowledge within the various knowledge elements to ensure an efficient use of the knowledge in the definition of the problem-solving architecture. The process of defining constraints may then have to conducted as one of consultation between agents specialized in different knowledge elements. When this is the case we would expect to find management teams and/or partnerships.

coordinating distributed knowledge may indeed decrease the more distributed that knowledge becomes. Again, the consequences of this lack of meta-knowledge will be more severe if the lack is located at the upper level of the problem-solving architecture rather than at the bottom-level. At the bottom level, lack of knowledge overlap has more local effects and shared knowledge may be created at lover costs by means of overlapping tasks. However, coordinative capabilities may be subject to a learning curve (Kirsten Foss 2001), so that, over time, firms may be able to internalize activities that involve increasingly distributed knowledge.

Conclusions

The notion of distributed knowledge has become a prominent concept for describing the knowledge conditions in which modern firms (allegedly) more and more often find themselves. Many writers have argued that these knowledge conditions imply that authority is becoming increasingly inefficient as a mechanism of coordination, an argument that served as a critical starting point for our discussion. We have argued that under certain conditions, authority may an efficient mechanism for performing the coordination task under distributed knowledge. Specifically, the following arguments were developed.

First, it is sometimes efficient to suppress distributed expert knowledge and base decisions solely on the knowledge of those who have authority; the gains from exploiting "authority of the office" may overwhelm the costs of suppressing "expert authority," as when urgent decisions are required. Thus, even under a narrow understanding of authority — what we have called Type I Authority — is it possible to argue that for reasons of efficiency, authority will the preferred coordination mechanism under distributed knowledge conditions.

More room for the exercise of authority under distributed knowledge is gained as we broaden the view of authority to also include what we have called Type II Authority, that is, delegating decision rights, constraining these, monitoring their use, etc. in such a way that an organization is created that matches a problem-solving architecture. When problems are completely or nearly decomposable, there will be ample room for the relatively independent application of distributed knowledge elements to sub-problems. However, the problem-solving architecture that allows for the application of distributed knowledge elements first has to be created and the residual interdependencies have to be managed. This provides room for the efficient exercise of authority.

We further sketched an efficient alignment framework in which the characteristics of knowledge elements and the structure of problems are dimensionalized and systematic relations between these dimensions and coordination mechanisms are hypothesized. However, the relation between distributed knowledge and authority is complex and contingent. Much complex work of a fundamental nature remains before a full efficient alignment framework can be put forward. Perhaps most fundamentally, what is strongly needed is a precise theory of distributed knowledge. Our conceptualization is preliminary and not entirely unambiguous. For example, it is an open issue how much overlap between individual knowledge elements that enter into a productive is consistent with the

notion of distributed knowledge. Also, we have no good notion of knowledge heterogeneity, which makes it problematic to speak of knowledge becoming more or less distributed. Before a more precise conceptualization and theory is put forward and operationalized for the purposes of management studies, it is hard to build precise theory on, for example, how distributed knowledge constrains the use of authority and how it impacts on the boundaries of the firm. Thus, the discussion in this paper should be taken as a first stab at an extremely complicated set of issues.

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Figure 1*: Discriminating Alignment*

		Structure of Problems		
		Decomposed	***Nearly decom-posed***	***Non-decom-posed***
Characteristics of Distributed Knowledge	***Some overlap among individual knowledge elements***	Pricing is the superior mechanism of coordination.	As interdepen - dencies become stronger, Type II Authority will increasingly dominate other coordination mechanisms.	Consultation dominates authority.
	Very little overlap among individual knowledge elements	Pricing is the superior mechanism of coordination.	As interdepen - dencies become stronger, and knowledge overlap decreases, Type II Authority will increasingly dominate.	Authority dominates consultation.